Probing PROBE: A field study of an advanced decision support prototype for managing Chemical, Biological, Radiological, Nuclear, and Explosives (CBRNE) events

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ABSTRACT

The purpose of this field study was investigate teamwork and communication among event management personnel, to assess the degree to which PROBE, the advanced prototype they were using to manage a CBRNE simulation, would adequately meet their needs. The study was a continuation of previous research conducted in the early phase of PROBE development. Two communication-related analyses were applied to identify instances of effective and of ineffective communication among the management team. These revealed that communication was mostly effective. However, the one serious communication breakdown that was observed could have had fatal consequences. It showed that great care must be taken to ensure the safety of first responders at all times when evaluating prototypes in the field. A list of questions was generated from the lessons learned to assist future researchers prepare for CBRNE field studies.

Keywords

Teamwork, communication, management decision support system.

INTRODUCTION

Emergency service responders (police, fire and hazardous materials, and emergency medical services (EMS)) deal with different types of emergencies as part of their daily routines (Kuban, MacKenzie-Carey, Gagnon, 2001). For example, the discovery of an unattended parcel left at an airport may lead to airport closure and the evacuation of people, which is time-consuming and costly (Stojmenovic et al., 2011). The unpredictable contents of the parcel, and the possible consequences, make it hard to manage such an event. The management of CBRNE events is highly complex; it includes crisis management in search and rescue situations, emergency medical events, or hazard mitigation (Waugh & Streib, 2006). A multidisciplinary team is tasked with managing a timely response to a potentially criminal action that may be large and dangerous.

Amid the chaos in a CBRNE event environment, and with the physical distance between different responders and responder groups, communication breakdowns are likely to occur because so much is happening simultaneously. Everyone in the command post is receiving information from different sources and via different technologies. Thus, for example, appointed first responders in the field are updating their team leader in the command post via radio; members of the command post are coordinating resources with dispatch via phone, and communicating with the incident commander in face-to-face interactions. In very large events involving mass casualties, public health authorities, surrounding hospitals, and other personnel may also be directly involved in the event management. The wide variety of communication modes and technologies can lead to misunderstandings and incorrect actions, some of which could potentially have fatal consequences.

In order to aid with CBRNE event management and communication, PROBE was created. PROBE is a prototype of a CBRNE management decision support system. Its purpose is to aid interoperability among response agencies by recording, storing, and sharing CBRNE event information thereby facilitating communication (Amita, 2008). The user population comprises predominantly commanders and operations officers involved in the event management. PROBE provides a suite of CBRNE management applications, CBRNE databases, standardized forms, automated evidence collection using RFID tags, and information on patient triage. The suite includes applications for hazmat technicians, for example, the Chemical Biological Response Aid (CoBRA), a large chemical database that includes another application, PALM Emergency Action for Chemical- WMD (PEAC-WMD). It stores information on chemicals that help to identify and render CBRNE materials safe (Amita, 2008). To support the bomb technicians, Socius, a database in which bomb technicians enter and store textual and photographic records of incidents involving explosive devices (Amita, 2008), is already fully functional. Socius has been implemented in the European Union in 27 languages and now goes under a different name there (EBDS Europol; Amita, 2014). Finally, the Rapid Triage Management Workbench (RTMW) and the Medical Command Post (MedPost) are designed to support EMS efforts. The RTMW (Lindgaard et al., 2006) tracks casualty information in one central database allowing all treatment centres, alternate care facilities, and hospitals to work with the same information. The Medical Command Post (MedPost) application is designed to help medical decision makers gain access to timely and accurate medical information in their effort to save lives. It provides caregivers with a higher-level view, helping them to identify, isolate and manage especially disease outbreaks and alert public health communities, as necessary, regardless of the magnitude of the event. It is thus particularly useful in the face of a potential radiological or nuclear threat.

In addition to linking all of these applications, PROBE will also be capable of supplementing real-time communication across agencies. This is especially important for the commanders located in the command post where it is often very busy and noisy, with multiple radios going simultaneously, and people coming and going. The mode of communication is predominantly face-to-face and via radio (Humphrey & Adams, 2006). PROBE will not replace the radios. Rather, it records and integrates communications and information during a CBRNE event, which also helps the commanders to produce their incident report after the event.

The remainder of the paper is organized as follows. The next section discusses teamwork and communication. Next, two analysis methods used in this paper are discussed. The results of the two analysis methods are presented thereafter, followed by the discussion and conclusion sections.

ANALYTICAL FRAMEWORK

Distributed Cognition and Cognitive Ethnography

In the framework of distributed cognition (Hutchins, 1995) knowledge and thought processes are shared between a person and their social (i.e. other people) and physical (i.e. tools and artefacts) environments (Hollan, Hutchins, & Kirsh, 2000). In investigations of group work, researchers examine people's activities, communications, and artefact interactions through detailed ethnographic study (Rogers, 2006). Studies of people/technology are fruitful for understanding the roles and functions of technology (Kirsh, 2004; Rogers & Brignull, 2003). Cognitive ethnographic field studies (Lewis, 1985) can provide data that can then be explained by distributed cognition (Hollan et al., 2000). It assumes that communication and activity, including breakdowns, are meaningful and culturally determined. Observations obtained via cognitive ethnography can inform designers of the usefulness of proposed modifications to interactive technologies (Dubbels, 2011; Williams, 2006; Kozlowski, 2003). Distributed cognition and cognitive ethnography were thus employed as frameworks, guiding the data collection and analysis processes.

Teamwork and Communication

Given that different agencies share the management of CBRNE events, excellent teamwork is essential. Teamwork is the interaction of two or more individuals working together to accomplish a common goal (Kozlowski & Bell, 2003) which, in a CBRNE event, is the management of the crisis (Lindgaard et al., 2006). In order to manage an event effectively, each team member is assigned specific tasks, much like each agency's responsibilities are divided among its members. Effective team coordination and collaboration (Reddy & Spence, 2008) involving extensive information exchange (Hazlehurst, McMullen, & Gorman, 2007), is essential to complete those tasks. Communication enables action planning and the forwarding of updates to modify action plans (Hazlehurst et al., 2007); it can also help teams recover from interruptions (Orasanu, 1994). Teamwork effectiveness can be measured by examining communication between team members (Bowers, Jentsch, Salas, Braun, 1998).

Instances of communication can vary in effectiveness. Communication is effective when the meaning of a message is successfully conveyed from speaker to listener. Closed loop is one of the most common examples of effective communication. It has three main parts: (1) the speaker initiates a message; (2) the intended listener receives, interprets, and acknowledges receipt of the message, and (3) the speaker ensures correct reception and interpretation of the message (Salas, Rosen, Held, & Weissmuller, 2009). For example, commander A tells commander B that there are 20 casualties; B responds that he will send in paramedics, and A closes the loop by saying "O.K.". We labelled such instances of effective communication closed loop communications here.

Ineffective communication comprises faulty verbal interactions such as ineffective timing (i.e. late), incomplete and/or inaccurate content, and key individuals not being informed (Lingard, 2004). A commander whose attention is divided between her radio and other commanders may only possess incomplete or inaccurate information, which decreases the response effectiveness. Open loop communication is another example of ineffective communication. It occurs when a speaker initiates a message or a question that is either not received, not interpreted, or not responded to (Salas et al., 2009). A communication breakdown occurs when there are consequences to an ineffective communication. To better understand teamwork and communication, it is necessary to explore where, when, why, how and the likelihood of communication breakdowns exists. In the research reported here, different types of utterances and aspects of communication topics were investigated using communication and content data analysis.

Communication Analysis and Content Analysis

Communication analysis involves the categorization of the topic (e.g. equipment, personnel, etc.) and type of each utterance (e.g. question, answer, etc.; Kramer, 2009; Hsieh & Shannon, 2005). The type of utterance helps to understand the information flow by demonstrating when information is needed (e.g. question) and when it is being shared (e.g. update). Hazlehurst et al., (2007), for example, studied coordination and collaboration among team members in a hospital environment by focusing their analysis solely on the type of verbal exchanges. That was done here as well. Sequences of communication types were examined for effective and ineffective communications.

Content analysis is a widely used technique (Hsieh & Shannon, 2005) applied to glean meaning from verbalizations. Analysis of communication topics is necessary for a thorough assessment of communication and teamwork in a command post. In latent inductive analysis, a researcher gradually generates topic categories, as they emerge from the data. Here, evidence of communication breakdowns was uncovered to understand communication and teamwork in the CBRNE event management environment.

METHOD

Participants

A sample of 15 experts participated in the study, representing 3 hazmat experts, 3 EMS officers, 3 police officers, 2 PROBE scribes, 2 event coordinators, and one software developer for PROBE. Of these, five were in the command post (1 EMS, 1 hazmat commander and his scribe, the police department IC commander and his scribe), and three were Ops officers (one per agency). The scribes' role was to transcribe into PROBE what the commanders communicated to other members of the response team. While the IC was in charge of managing the CBRNE event, the event coordinators were in charge of managing the logistics such as monitoring the progression of the scenario and planning lunch. Participation in the simulation was a part of their normal day jobs; permission for the researchers to be present had been granted a priori by all concerned and approved by the Carleton University Psychology Department's Ethics committee.

Design and Apparatus

Two researchers located in the command post observed the command post team members during the simulation, from opposite sides of the room. Each researcher was equipped wirh a video camera (Sony Handycam DCR-SR-300 HDD). Three audio recorders (Olympus WS-311M Digital) were located in different areas of the command post in which four laptop computers were set up (1/ EMS, hazmat, police; 1 one for the IC). Verbatim utterance transcriptions were transferred to NVivo 9.0 for digitalized analysis.

Procedure

The event organizers first explained the purpose of the researchers' presence and task to the participants. Then, participants read and signed the informed consent form before the researchers proceeded to the command post for their observations. All verbal interactions in person, radio, and software communication were recorded. At the end of the event, all commanders were given debriefing forms thanking them for participating. Finally, a briefing session was held for all participants and the researchers.

Data Analysis

In an effort to re-construct the entire event, all video and audio recordings were transcribed ad verbatim and merged into a single file to compare activities across all command post members. Recordings were viewed multiple times to identify and verify the identity of the speakers and listeners of verbal communications. In order to focus the analysis, talk unrelated to the event management was removed from the transcript, as was done previously (Stojmenovic et al., 2011). For communication analysis, the researcher focused on the types of utterances, and on the communication topics and contents for latent inductive content analysis. Meaning was extrapolated from the categories to identify and compare instances of effective and ineffective communication.

RESULTS

A description of the event is provided first, followed by the communication analysis findings reporting instances of effective and ineffective communication. Next, the latent inductive content analysis results are shown in which the severity of ineffective communications was assessed. Then, the inter-rater reliability of the two analysis methods is presented. A summary of communication and teamwork follows next, and finally the CBRNE simulation event management goals are outlined.

Event Description

According to the scenario that the response team were given at the outset of the simulation, police officers had found a makeshift lab in a storage container in the Port of Saint John. This area was labelled the hot zone. A command post was set up to manage the response. The data were divided into two phases, comprising approximately an hour and a half each, because two separate Incident Action Plans (IAP) were prepared during the simulation. Phase 1 was executed as the first group of responders went into the hot zone to gather information on the severity and magnitude of the situation. They found two dangerous chemicals. Later, an activated bomb was detected as well. Phase 1 therefore ended with the deactivation of the bomb and the removal of casualties. Phase 2 involved the planning and execution of the second IAP, for the re-entry of police and hazmat first responders to collect evidence and cleanup the site. EMS officers were on standby.

Communication Analysis Results

Communication analysis, divided into two steps, focused on utterance types. First, each utterance was coded by type, as they emerged from the data. Then, sequences of effective and ineffective communication were identified.

Step 1: utterance coding. There were a total of 1897 utterances in the entire simulation. The volume of communication was fairly similar in Phases 1 and 2. Anecdotally, there seemed to be more activity in Phase 1 in which the most dangerous parts of the event were handled: the chemical was neutralized, casualties were identified and removed from the hot zone, and the bomb was deactivated. One would have expected a high frequency of communication, allowing commanders to organize the response, leaving little need for activity in Phase 2. However, the commanders were more involved in altering the second IAP for re-entry into the hot zone for cleanup and evidence collection than for the first IAP.

A total of fifteen utterance-type categories emerged from the transcript. These are all listed in the leftmost column of Table 1 below. A definitions is given of each type in the centre column, and the rightmost column gives examples of the utterance types uncovered.

Utterance Type	***Definition***	***Example***
Acknowledgment	Response from listener of a communication, letting speaker know that they received the message.	Yeah; ok; roger; 10-4.
Answer	Responses specific to questions.	It was red.
Attention Granting	In response to attention requests, let speaker know that listener is paying attention and communication can proceed.	Ops (K): Go ahead.
Attention Request	Demands for awareness, from speaker to listener, precedes a communication.	HC to HOp: Operations officer, this is fire in command.
Clarification Granting	Clarifying or rewording a previous communication.	Yea, today.
Clarification Request	Asking for clarification on a previous communication.	Do you mean today?
Complaint	Expressions of discontent.	I would never use this. It's not working.
Explanation	Justifications and reasons for giving a previous communication.	Here's why this is important: 'cuz they are going to create an IAP.
Joke	Intended to amuse, important for alleviating stress.	Fire to police: Do you want to let them know that firefighters are awesome?
Order	Instructions or commands to further action.	IC to HCo: Call your fire Ops.
Question	Requests for information.	What colour was it?
Repetition	Forwarding newly learned or planned information.	HCo to HOps: The IAP has been signed.
Statement	Expressions of ideas or facts.	That's all I can tell you.
Suggestion	Proposals of possible solutions to problems.	You might get it by clicking here.
Update	Providing the most recent information available.	Just so you know, we found an IED.

Table 1. Communication analysis types of utterances, as they emerged from the entire transcript

Step 2: utterance sequence analyses: Since each utterance is examined in isolation to categorize communications by type in communication analysis, that method did not lend itself to identify effective and ineffective communications. To achieve that, sequences of communication belonging together were therefore identified and classified separately. A total of 78.9% of all communication instances (Phase 1 (P1): n = 136; Phase 2 (P2): n = 133) were found to be effective, leaving 21.1% of communications deemed ineffective (P1: n = 4; P2: n = 0). (P1: n = 39; P2: n = 33. These were open loop (P1: n = 8; P2: n = 18), issues due to PROBE (P1: n = 14; P2: n = 3), misunderstandings (P1: n = 4; P2: n = 6), time lags (P1: n = 5; P2: n = 4), key individuals uninformed (P1: n = 4; P2: n = 2), and incomplete information).

Open Loop Communications occurred most frequently, mainly in Phase 2. These were unanswered questions, unfilled clarification requests, requests for attention, and unacknowledged communication.

PROBE-related issues were due to unfamiliarity with PROBE and software shortcomings. A 1-day training session was held the day before the event for all but one participant. In the simulation, PROBE did not receive all communications; there were too many functions for participants to recall. Communication received by PROBE goes to the IC, who disseminates the information to the team. The IC's scribe had not been trained in PROBE usage and was therefore unaware of that responsibility and how to execute it. Furthermore, screens had to be manually refreshed, a function the EMS commander had forgotten, and which caused issues when the EMS Ops officer attempted to communicate via PROBE. The information believed not to have been forwarded by the IC scribe caused the EMS commander to rely heavily on radio communications until a PROBE developer reminded her of the manual screen refresh, halfway into the simulation. However, many messages for the EMS commander had been missed. While most PROBE functions worked as intended, the sending and receiving of file attachments such as the IAP, did not. User unfamiliarity with the functions, together with variations in the wireless network strength caused failure in receiving PROBE messages. These variations were due to the wider than anticipated distribution of laptops throughout the area that went unaided by signal repeaters. In addition, the network hardware turned out to be unsuitable for in-vehicle usage, as the signal strength of the device could not easily penetrate the insulated vehicle steel walls. These problems could be addressed through use of a device capable of broadcasting and sustaining stronger network signals and calibration of the system. The severity of these problems is addressed in the latent inductive content analysis section. The remaining types of ineffective communications occurred rather infrequently.

Latent Inductive Content Analysis Results

In order to assess the severity of the ineffective communications, the latent inductive content analysis focused on the utterance topics. It was also divided into two steps: (1) coding each utterance by topic as it emerged from the data, and (2) determining the severity of each.

Step 1: coding. Seven content categories emerged from the transcript, namely (1) PROBE (P1: n = 487; P2: n = 316), (2) action plan (P1: n = 107; P2: n = 161), (3) personnel (P1: n = 92; P2: n = 68), (4) event (P1: n = 47; P2: n = 95), (5) equipment (P1: n = 53; P2: n = 62), (6) communication (P1: n = 25; P2: n = 54), and (7) offending agent (P1: n = 58; P2: n = 17). Utterances were categorized as 'Action Plan' if they pertained to the CBRNE response planning process (e.g. *Did you sign the action plan?*). An utterance was classified as a 'Communication' if it was about talking to or contacting others, unrelated to communication done through (e.g. *Did she just say something?*). The content of an utterance was 'Equipment' if it was about any CBRNE response tool except PROBE (e.g. *A level B suit would be sufficient, really).* If the utterance was about the management of the simulation (unrelated to the CBRNE threat), it was about the "Event" (e.g. *lunch will be served*). If the utterance was about the CBRNE threat, then the topic was offending agent (e.g. *IED found*). If the utterance was about the staff, then the topic was personnel (e.g. *medic needed*). An instance of communication was about 'PROBE' if it was about the advanced prototype or an action associated with it (e.g. *Did you get that? I tried to send it through there*.).

PROBE was the most talked-about topic, accounting for 48.9% of the utterances. It was discussed more frequently in Phase 1 than in Phase 2, mainly due to users familiarizing themselves with it, discussing concerns and PROBE usage. Despite PROBE communications only marginally affecting event outcomes, discussion was more focused on PROBE rather than action plans, equipment and other response-related issues. For instance, the hazmat commander chose to forego a situation status update – a meeting amongst ops officers and commanders to report progress, in favour of learning more about PROBE. In addition, PROBE was not unilaterally used, which caused occasional disruptions in information flow along the chain of command.

Although the commanders make crucial strategic decisions necessary to manage the event, planning and revising the action plan was their primary purpose, yet planning only accounted for 16.3% of all communication. The IAP was discussed more often in Phase 2 because the commanders altered the second IAP. However, the presence of the Ops officers reduced most of the need for planning in the command post. Discussions about personnel occurred more frequently in Phase 1 in which commanders were getting acquainted with everyone's teams and clarifying who would be among the first entry team's members. In Phase 2 where everyone knew who was in the response team, the topic was discussed less frequently. Simulation management discussions such as lunch and coffee breaks doubled in Phase 2. Discussions about equipment other than PROBE remained relatively constant; they were about radio frequencies in Phase 1 and Personal Protective Equipment (PPE) in Phase 2. Conversations with other personnel doubled in Phase 2, as commanders talked about sharing information down the chain of command and asked about other communications more often. Communication about the offending agents was minimal in Phase 2 as they had already been neutralized and deactivated in Phase 1. The finding that the event management was discussed more frequently than equipment or personnel suggests that the ops officers were experienced requiring little or no input from the senior officers.

Step 2: assessing the severity of ineffective communication. The severity of ineffective communications was assessed by examining the topic of each instance as well as the types and topics of utterances immediately following the ineffective communication to identify the consequences. This level of analysis is not included in the content analysis literature, but it was necessary to understand the severity of ineffective communications. In total, 23.6% (n = 17) of all ineffective communications were PROBE-related. However, only one of these resulted in a communication breakdown. Others were averted because the commanders used their radios as backup when information was not coming in through PROBE.

The single communication breakdown that had a severe consequence occurred in Phase 2. It involved a hazmat first responder and an Explosive Disposal Unit (EDU) who were dressed in high-level PPE, which are air-tight safety suits for highly dangerous situations with a limited supply of oxygen. The hazmat commander received a radio update from his ops officer which the IC overheard and requested clarification. The two responders had lost their air supply. Apparently, the EDU and hazmat first responder were suited up, waiting for forensics responders to enter the hot zone. The EDU officer's radio signal was too weak to enable him communicate with his team, relying instead on the hazmat first responder. Meanwhile, the police forensics officers were waiting for the commanders' approval of the second IAP before moving in. However, the Ops officers' proposed IAP had not yet reached the commanders since PROBE was not forwarding attachments. Therefore, the document had to be written and physically brought to the commanders. It took the commanders, who were unaware of the event unfolding in the hot zone, another six minutes to approve the IAP, and entry was to take place approximately ten minutes after that. However, because the commanders were then told that only a negligible amount of radiation had been detected, the responders now needed to wear a lower level of PPE. This change delayed the response team so that the forensics team finally made entry two minutes later than the original ten minutes planned after the second IAP was approved. This timeline is shown in Figure 1 below. The moment the IC was notified that the forensics had entered the hot zone, the hazmat commander was informed that the EDU and hazmat officer were running out of air in their air-tight PPE. Apparently, the EDU officer had gone to the decontamination area, but no one was there so he had actually run out of oxygen, collapsing to the ground. Thankfully, nearby hazmat first responders discovered him and removed his suit. This chain of events was surprising as the EMS commander had ordered a paramedic to get suited up in PPE and stand-by the hot zone, three minutes before the second incident action plan was approved. This should have given the paramedic enough time to get ready and be in position by the decontamination area. The reason for the lack of his immediate presence and assistance is unknown. Other than that unfortunate incident, "the exercise went excellent[ly]", according to the police Ops officer.

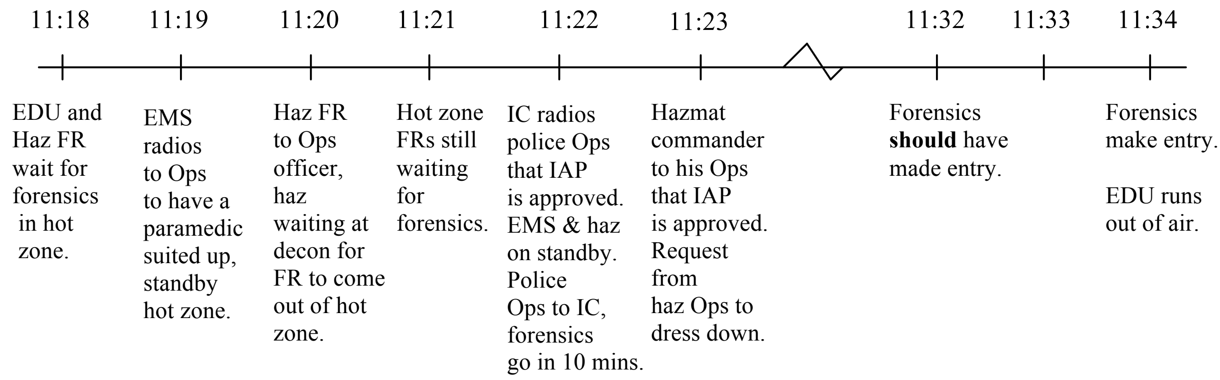

Figure 1. Timeline of the event in which a responder ran out of oxygen.

Inter-Rater Reliability

To determine the inter-rater level of reliability, another researcher who was not present at the simulation and unfamiliar with CBRNE events categorized each utterance from a randomly selected 10% of the transcript by type and content of communication. For the communication data analysis, agreement was 70.2%. The main discrepancy was due to the second researcher misclassifying clarifications requested or granted as questions and answers. For latent inductive content analysis, agreement was 62.9%. The main issue here was that the second researcher was largely unfamiliar with the context of PROBE, so she labelled many 'PROBE' communications as 'equipment'. All disagreements were settled by negotiation.

Communication and Teamwork

As a social network analysis is reported in detail elsewhere (Stojmenovic & Lindgaard, 2013) only a summary of the speaker-related findings is provided here. The hazmat commander spoke most frequently, closely followed by the IC and the EMS commander. One would have expected that the IC should speak most frequently of all because he is in charge of the entire event. However, as the hazmat commander was older than the IC, he may also have had more experience in the command post. At the beginning of the event, the IC informed the other commanders that their advice was welcome. Later, he commented that he missed being involved hands-on with the response, saying that he found that "when you move on, you start to miss the things you used to do", motioning towards the hot zone as he spoke. It is thus possible that a difference in experience may explain the apparent reversal of speech frequency between the two officers. In addition, even though a bomb was involved in the event, the IC who was from the police department, did not communicate more because he was only notified about it when it had just been found, and when it was deactivated. His advice on how to handle it was therefore not needed. Although the IC is in charge of the event, and therefore is responsible for making the biggest decisions, in the present case, it was unclear if he changed the incident action plan before approving it, which was the biggest decision to be made. Since the researchers did not have access to that file, it can only be speculated that the IC had more input when approving it, and his input was not discussed.

The EMS commander spoke the least of the three commanders, perhaps because there were only three 'casualties', presented in the form of pie plates with symptoms written on them. The 'patients' therefore did not require attention. The EMS first responders' duties were limited to monitor the vital signs of teammates entering and exiting the hot zone - a routine task for paramedics, not requiring a lot of communication.

Taken together, of the 21.1% ineffective communications, only one led to a breakdown. The content and context of these utterances showed that 63.4% of all ineffective communication instances occurred between commanders and ops officers, mainly due to misunderstandings with PROBE. The remainder occurred among commanders, scribes, the PROBE developer, and the event mangers. Only 11.1% of ineffective communications occurred between commanders, suggesting that communication among commanders was highly efficient and effective. This is probably because the commanders were collocated in a fairly calm and quiet environment, and could hear each other's radios, leaving little room for confusion. The common goals of neutralizing the chemical, deactivating the bomb, treating patients, and collecting evidence were all completed in a timely fashion. The one communication breakdown was not an intended part of the simulation scenario. However, the high frequency of effective communication, and the ability efficiently to overcome breakdowns when they did occur, suggests that the overall teamwork among commanders and ops officers was effective and successful.

CBRNE simulation goals voiced during debriefing

During the debriefing session, members of the agencies expressed their simulation goals. Fire and hazmat's goal was to expose responders to hands-on CBRNE training. For example, when approving the second IAP for re-entry into the hot zone, the IC asked the hazmat commander "Why would they have to go back in?" The hazmat commander replied, "I think it's just for the practice... I think they're just getting guys into suits." In addition, the hazmat and police teams wanted to practice working with the other agencies. The police personnel were from other cities in New Brunswick, representing different agencies and different levels of Government. The EMS goals were to test the usability of a new worksheet and to test PROBE. The EMS team had recently become a Provincial team; in case of a larger CBRNE-related event, any paramedic in the province could be dispatched to the scene. Therefore, some procedures for large-scale events were being changed, requiring new forms. Testing PROBE was a goal the commanders had, explaining why they relied so heavily on it for communication and used it throughout the event. Journalists had been invited to the simulation, which may have altered the atmosphere. Reporters were everywhere, recording the command post, and interviewing event coordinators at the beginning of Phase 1. The commanders may thus have acted more casually, which may account for the jokes and socialization that occurred.

DISCUSSION

The role of PROBE

PROBE was intended to aid communication, supplement decision making, and facilitate effective teamwork. Some issues did arise because PROBE was still a prototype under development, albeit reasonably advanced. Other issues arose because responders had only received a minimum of training on the software the day prior to the simulation. In the command post, more time was spent testing PROBE than managing the event, leaving little necessity for teamwork and decision making. PROBE did supply a summary of the entered events, to aid in writing the incident report, a summary of the event response and outcome by CBRNE responders. The observation that the IC had to forward messages on PROBE to other team members was a procedural issue in the PROBE interface. The implemented PROBE will enable users to send messages directly to intended individuals without needing clearance from the IC. The need to refresh the screen manually will also be eliminated. Also, the ability to attach and send different file formats will be added. Ideally, there will also be an automatic monitoring and alert system to notify appropriate personnel of mishaps/near misses. In the incident above, the fact that some responders were running low on oxygen should have been noted by PROBE. With PROBE fully operational, responders will be able to communicate even if their radios are not working. It will also help to create detailed incident reports as team members representing each agency must deliver upon completion of a CBRNE event or simulation. Access to the CBRNE information sources necessary for successful event management will also prove an advantage for emergency response teams.

Modification of analysis methods.

At one level, communication analysis and latent inductive content analysis were adequate for this research. Communication analysis facilitated understanding of how information was being shared. However, at another level, the method as described in the literature did not entirely meet the analytic requirements. Communication sequences were analyzed to identify effective and ineffective instances. This added step provided local context enabling the researchers to see which utterances demanded a response, and when responses did/did not occur. It would thus appear that examination of sequences is essential when interpreting data intended to yield an understanding of communication effectiveness in instances in which effectiveness is determined by open- and closed loop communication. Latent inductive content analysis was used to categorize the topic of each utterance to determine the severity of ineffective communications. This too required an additional step to what is described in the literature. The original analysis involved the coding of all utterances by topic, and the examination of the utterance topic(s) involved in the ineffective communication. The additional step involved examination of types and topics of utterances immediately following the instances of ineffective communication. This was necessary to reveal the consequences of such communications as well as to determine the severity of ineffective communications.

Taken together, these additional steps helped the researchers gain a deeper understanding of communication in the command post during the CBRNE simulation. Although it is acknowledged that these additional steps may not always be necessary, it would be helpful for future researchers to refine the descriptions of these two analysis methods in the literature by including them. The next step towards such refinement would thus be to identify the circumstances under which such additional scrutiny of data is required.

One interesting issue concerns the separation of communication and content analyses. Communication analysis as described by Kramer (2009) included both the type and the topic of utterance, whereas, following other published research (e.g. Hazlehurst, 2007), these were kept separate in this research. These two methods were kept separate in this paper as we postulated a higher yield of information through different approaches. However, in order to gain a better understanding of communication, it was important to analyze the type and topic for each utterance simultaneously. Keeping communication and content analyses separate was thus not necessary. It is therefore suggested that the method applied by Kramer (2009) be used.

CONCLUSION

Although all but one participant had received training a day before the simulation, this proved insufficient for them to recall all PROBE's features. One way this could be prevented in a future simulation would be to provide responders a quick review of the software capabilities immediately before the simulation. In addition, a pocket-size cheat sheet would have been beneficial for the participants in the present research. This may have prevented, or at least reduced the consequences of the mishap. Some kind of alarm incorporated into the PPE to signal oxygen levels to the wearers as well as to the personnel on standby would also be beneficial.
Some of the details concerning the simulation reported here were only revealed in the final briefing, but it would be helpful for researchers to know more about the management structure, the scenario, the magnitude of the event, and the number of professionals expected to take part in it ahead of time. Because of this, the list of questions shown in the Appendix was devised to help future researchers plan and organize field data collection strategies when observing multi-agency emergency responses.

CBRNE simulations are expensive, time-consuming, and infrequently open to researchers. Opportunities for research involvement in such simulations afford empirical contributions of data collection and analysis methods. The above results yielded a better understanding of crisis management that may be extrapolated to similar domains, such as the army. The research presented here could facilitate future efforts pertaining to decision support system prototypes based on our points of success and failures. The list of questions is intended to help researchers better to prepare for observing future CBRNE events.

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REFERENCES

1. Amita, (2008). PROBE Crime Scene Support Tool for Police, Hazmat, EMS, AER & VFR, Poster.
2. Amita, (2014). Products – Socius/Plus!. *Amita.Solutions.People*, http://www.amita.com/productssolutions/sociusplus/.

3. Bowers, C.A., Jentsch, F. Salas, E. and Braun, C.C. (1998) Analyzing communication sequences for team training needs assessment, Human Factors, 40, 672–679.
4. Dubbels, B. (2011) Cognitive Ethnography: A Methodology for Measure and Analysis of Learning for Game Studies, International Journal of Gaming and Computer-Mediated Simulations, 3, 1, 68-78.
5. Hazlehurst, B. McMullen, C.K. Gorman, P.N. (2007) Distributed cognition in the heart room: How situation awareness arises from coordinated communications during cardiac surgery, *Journal of Biomedical Informatics*, 40, 539-551.
6. Hollan, J., Hutchins, E., and Kirsh, D. (2000) Distributed cognition: toward a new foundation for human-computer interaction research, *ACM Transactions on Computer-Human Interaction*, 7, 2, 174-196.
7. Hsieh, H.F., Shannon, S.E. (2005) Three approaches to qualitative content analysis, *Qualitative Health Research*, 15, 9, 1277-1288.
8. Humphrey, C.M. and Adams, J.A. (2011) Analysis of complex team-based systems: augmentations to goal-directed task analysis and cognitive work analysis, *Theoretical Issues in Ergonomics Science*, 12, 2, 149–175.
9. Hutchins, E. (1995) How a cockpit remembers its speed, *Cognitive Science*, 19, 265-288.
10. Kirsh, D. (2004) Metacognition, Distributed Cognition and Visual Design, in P. Gardinfas, & P. Johansson, (Eds.) *Cognition, Education and Communication Technology*, Lawrence Erlbaum.
11. Kozlowski, S.W.J. and Bell, B.S. (2003) Work groups and teams in organizations, in W. C. Borman, D. R. Ilglen, R. J. Klimoski (Eds.), *Handbook of psychology: Industrial and organizational psychology*, London: Wiley, 12, 333-357.
12. Kramer, C. (2009) Communication linking team mental models and team situation awareness in the operating room, *Master's Research*, Carleton University
13. Kuban, R. MacKenzie-Carey, H. Gagnon, A.P. (2001) Paper #4: Disaster Response Systems In Canada, Institute for Catastrophic Loss Reduction.
14. Lewis, I.M. (1985) Social Anthropology in Perspective. Cambridge: Cambridge University Press.
15. Lindgaard, G., Dillon, R., Trbovich, P., White, R., Fernandes, G., Lundahl, S., and Pinnamaneni, A. (2006) User Needs Analysis and requirements engineering: Theory and practice. Interacting with Computers, 18, 1, 47-70.
16. Lingard, L. Espin, S. Whyte, S. Regeh, G. Baker, G.R. Reznick, et al. (2004) Communication failures in the operating room: an observational classification of recurrent types and effects, *Qual Saf Health Care*, 13, 330–334.
17. Mickan, S.M. and Rodger, S.A. (2005) Effective health care teams: A model of six characteristics developed from shared perceptions, *Journal of Interprofessional Care*, 19, 4, 358-370.
18. Orasanu, J. (1994) Shared problem models and flight crew performance, in N. Johnston, N. McDonald, R. Fuller (Eds.), *Aviation psychology in practice*, Aldershot, UK: Ashgate, 255-285.
19. Parush, A., Kramer, C. Foster-Hunt, T., Momtahan, K., Hunter, A. Sohmer, B. (2011) Communication and team situation awareness in the OR: Implications for augmentative information display, *Journal of Biomedical Informatics*, 44, 477–485.
20. Reddy, M.C. and Spence, P.R. (2008) Collaborative information seeking: A field study of a multidisciplinary patient care system, *Information Processing and Management*, 44, 244-255.
21. Rogers, Y. (2006) Distributed Cognition and Communication, In *The Encyclopedia of Language and Linguistics 2nd Edition*. Edited by Keith Brown Elsevier: Oxford, 181-202.
22. Rogers, Y. and Brignull, H. (2003) Computational offloading: Supporting distributed team working through visually augmenting verbal communication, *Proceedings of the 25th Annual Cognitive Science Society Conference, Boston.*
23. Salas, E., Rosen, M.A., Held, J.D. and Weissmuller, J.J. (2009) Performance Measurement in Simulation-Based Training: A Review and Best Practices, *Simulation & Gaming*, 40, 3, 328-376.
24. Stojmenovic, M. Dudek, C. Noonan, P. Tsuji, B. Sen, D. and Lindgaard, G. (2011) Identifying user requirements for a CBRNE management system: a comparison of data analysis methods, In proceedings of the *8th International Information Systems for Crisis Response and Management Conference*, Lisbon, Portugal.
25. Stojmenovic, M. & Lindgaard, G. (2013). Benefits and Limitations of the Social Network Analysis when explaining instances of ineffective communication in two Chemical, Biological, Radiological, Nuclear, and Explosives simulations. In Proceedings of *2013 IEEE Third International Conference on Cloud and Green Computing,* 327-334.
26. Waugh, W.L.Jr. and Streib, G. (2006) Collaboration and leadership for effective emergency management, Articles on Collaborative Public Management, special issue, 131-140.
27. Williams, R.F. (2006) Using cognitive ethnography to study instruction, in *Proceedings of the 7th International Conference of the Learning Sciences*, Bloomington, Indiana: 838 – 844.

APPENDIX

Data Collection Planning and Organization List of Questions: What is the name of the simulation? What is the date of the simulation? Contact information ((i.e. phone number, email, etc.)? How many people will take part in the simulation? What will the response management structure be (i.e. ops?)? Where will each layer of the response be set up? What are the goals of the simulation from these different perspectives: (1) the event organizer(s), (2) the incident commander, (3) other commanders, (4) potential Ops, and (5) anyone else (e.g. software developer)? What agencies will be involved? What are their respective roles? What will the scenario be? Where will the event take place (physical environment)? How many researchers would you need to cover all intended areas? How much equipment will you need? Is the equipment chronologically synchronized? Are all of the equipment's batteries fully charged?